EUV Mask Blank Manufacturing Solution Within Reach: Immediate Challenges

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Veeco Team:

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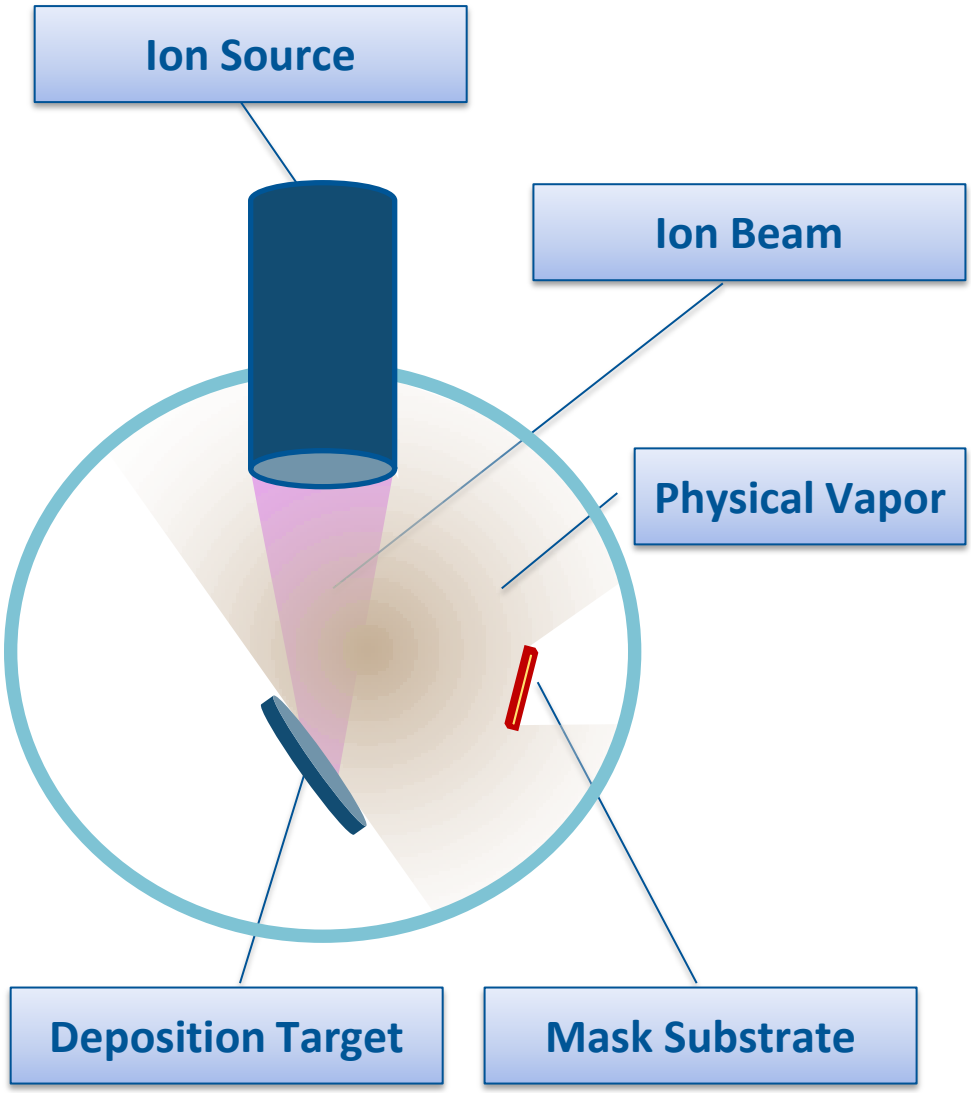
And those who have contributed to this work, but might be missed from here

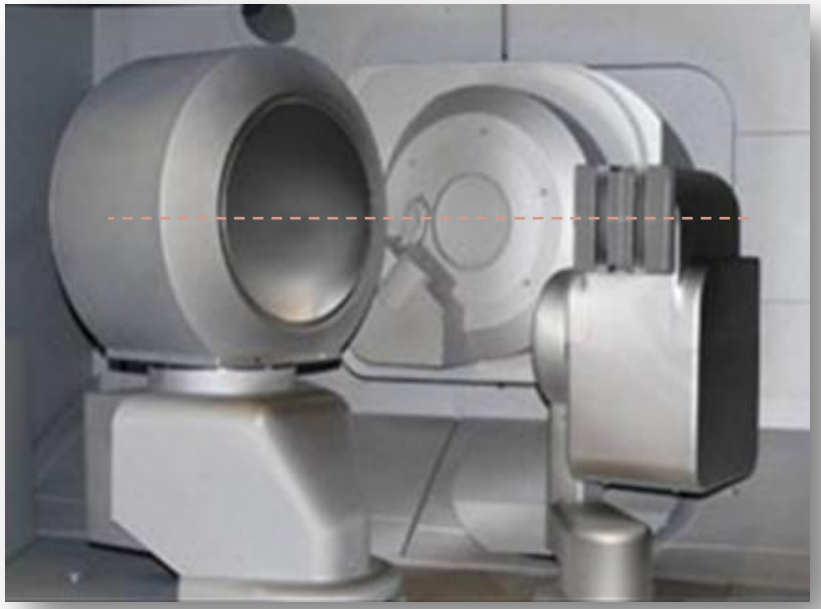
Outline

- Intro: Tool, FA
- *Pareto*
- Yields: on Total- & Adder-Defects
- Defects: *z*-Locations and Compositions
- HVM Solution?
- Conclusions

Veeco EUVL Mask Blank Deposition System: *IBD*



Top-view diagram of Veeco IBD configuration

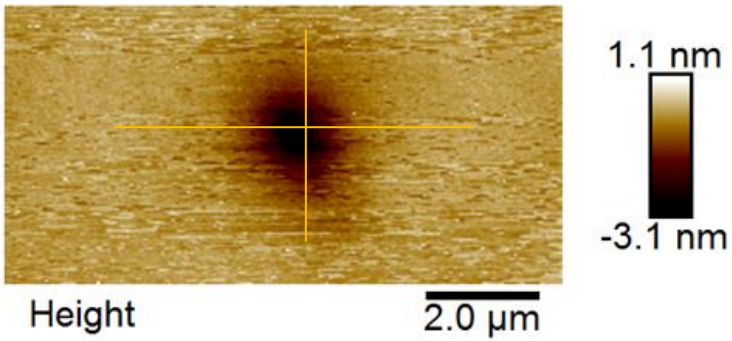


Front-view Veeco IBD configuration

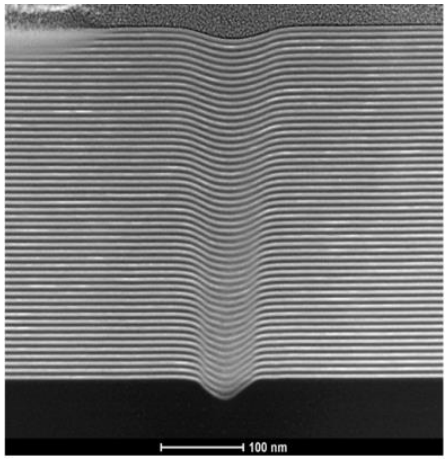
*In this paper, data from two ion optics configurations will be reported, referred to as "**POR**" and "**NEW**".*

Mask Blank Multilayer Defect Analyses

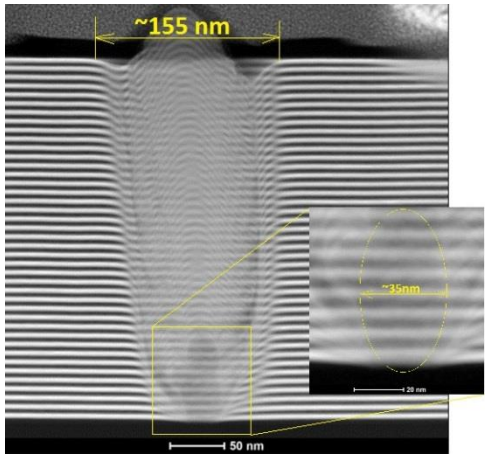
Defect analyses for element, morphology, size and vertical location
(AFM, FIB SEM, EDS, TEM)



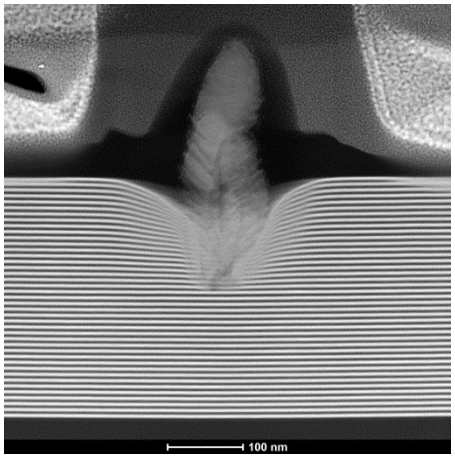
ML Defect decorated from substrate Pit: ~4nm deep in ML



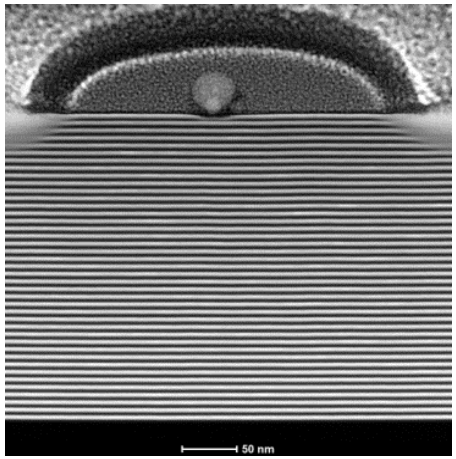
Decorated from substrate pit



Decorated from substrate particle



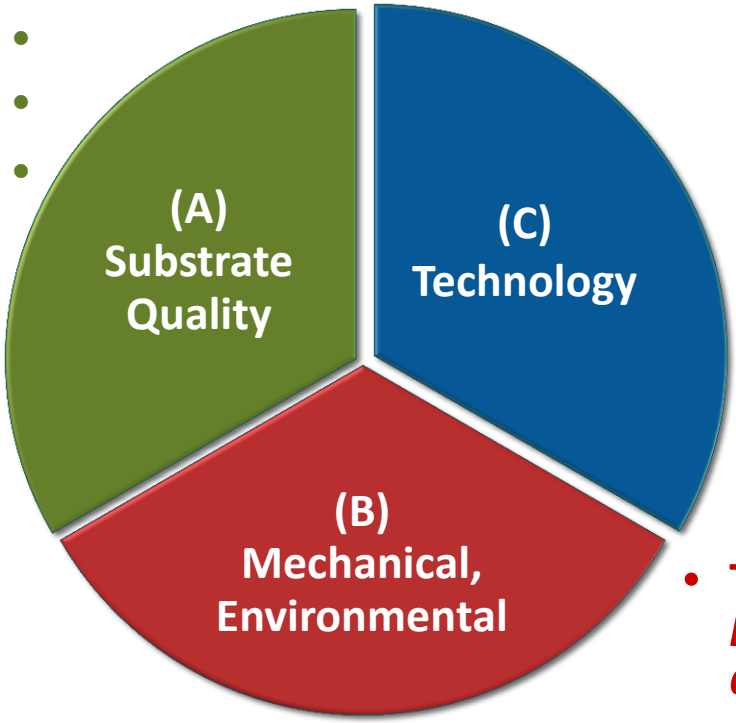
Adder-defect landed during ML deposition



Surface defect after ML deposition complete

Mask Blank Defect: *Pareto*

- LTEM material
- Substrate CMP
- Cleaning



- Ion optics
- Targets
- Chamber shields
- Deposition process

- **Tool components: *such as loadlock, gate valves, e-chuck, and robots, vacuum…***
- **Handling outside dep. tool**

*Mechanical, environmental particles measured with **FPM** (Full-Path particle Monitor) in this work*

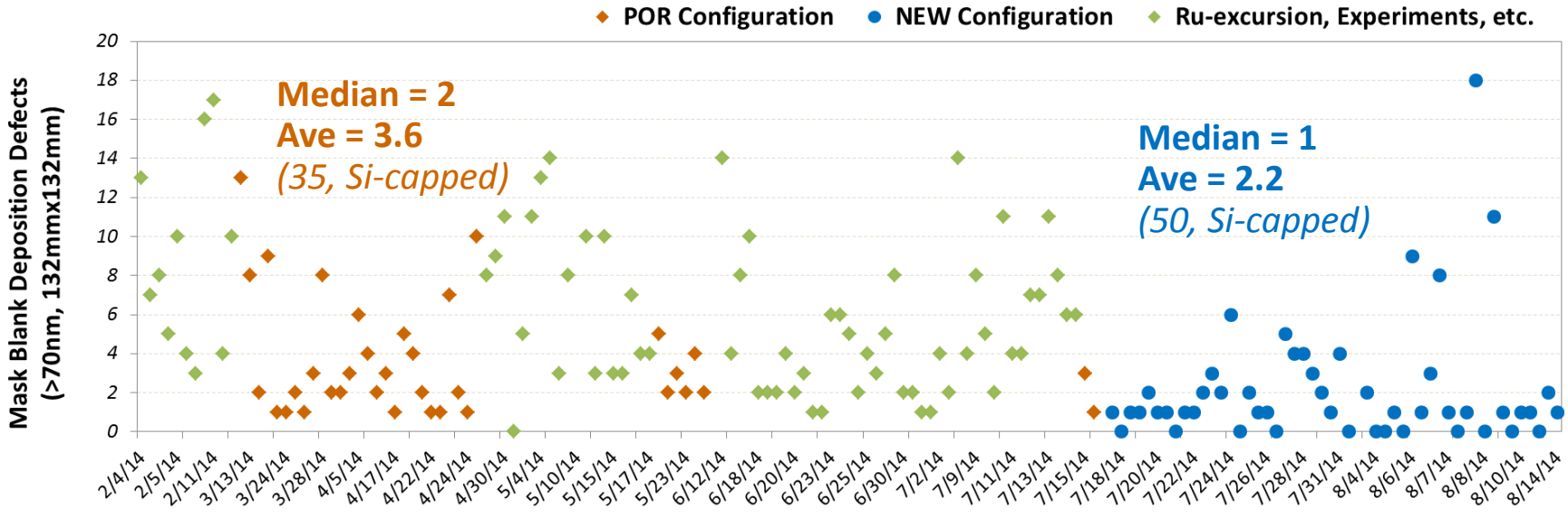
- **Total ML Defects = B + C + A**
- **ML Dep. Defects = B + C**

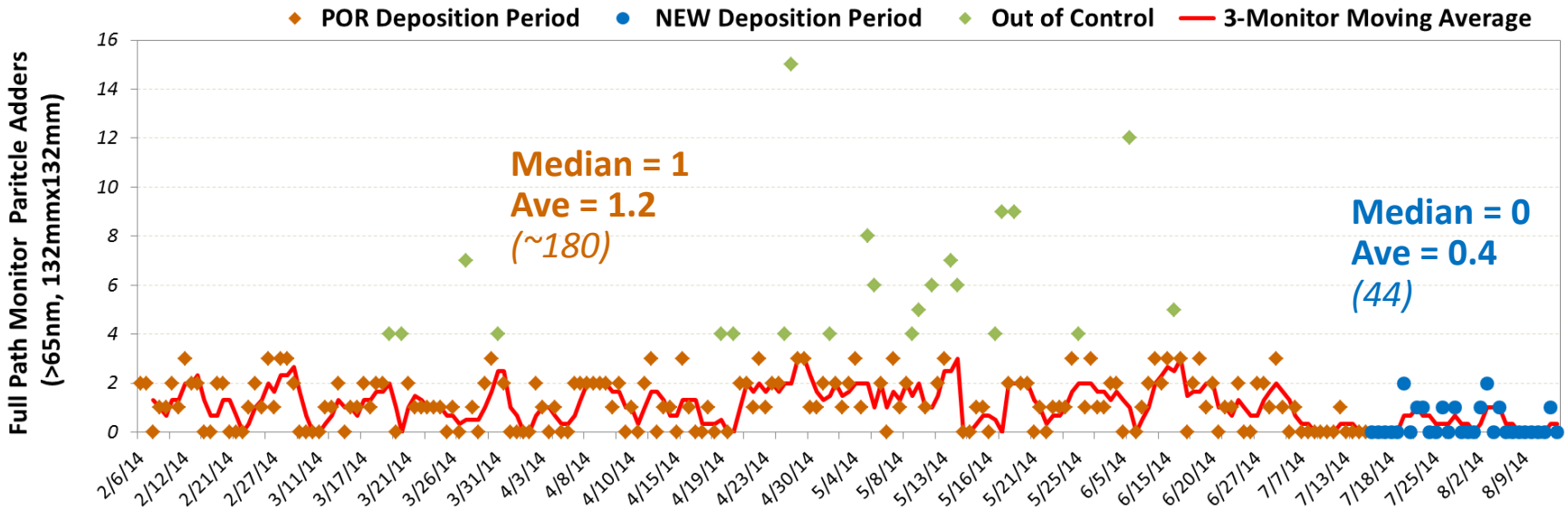
+

Decorated Sub-sensitivity Substrate Defects

Multilayer Defects & FPM Particles: *All Raw Data*

Yield discussions in this paper are all based on the 50 multilayers of NEW configuration.





Defect-Free Mask Blanks: *4% Yield, @54nm*

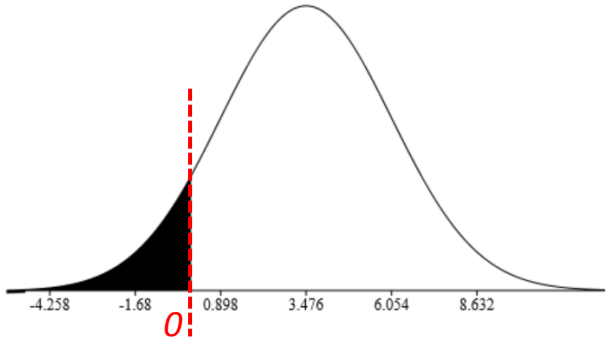
Total defect maps

08/12/14 08:57
[Sample Information]

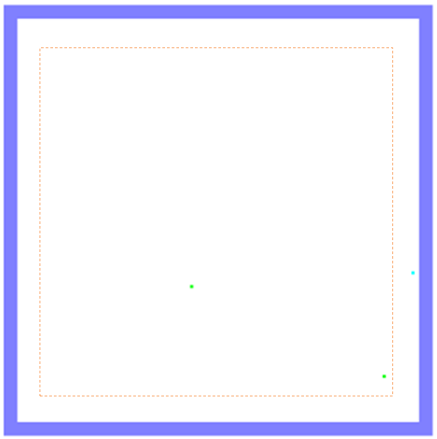
Sample ID	:
Lot ID	:
Cassette/Slot No.	: 2 - 1
WFD File	: D:\def003a\Mask-142mm.wfd
Work Folder	: Step 7900
LDF File	: Lot_DRT1408004_7900_140812073658.ldf [Count = 3]
Sample Size	: 152 mm
Comment	:

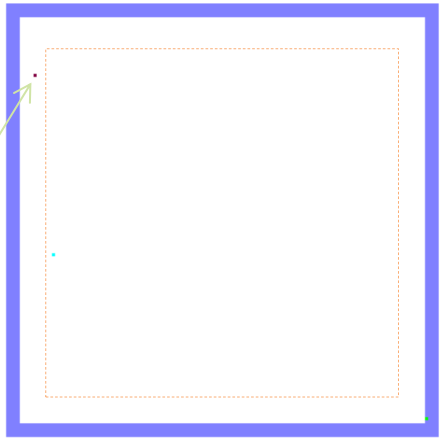
08/06/14 13:09
[Sample Information]

Sample ID	:
Lot ID	:
Cassette/Slot No.	: 2 - 1
WFD File	: D:\def003a\Mask-142mm.wfd
Work Folder	: Step 7900
LDF File	: Lot_DRT1407055-90d_7900.
Sample Size	: 152 mm
Comment	:

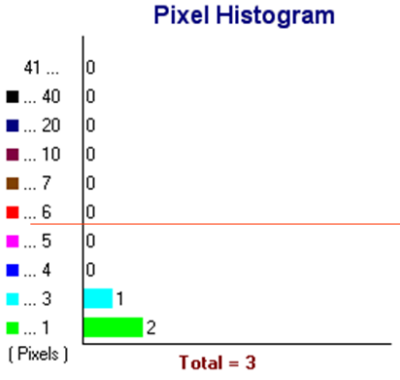


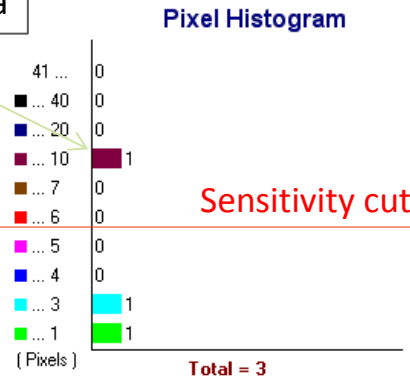
Probability for defect-free:
~8.9%
(mean: 3.5, S: 2.6)





Substrate pit outside quality area

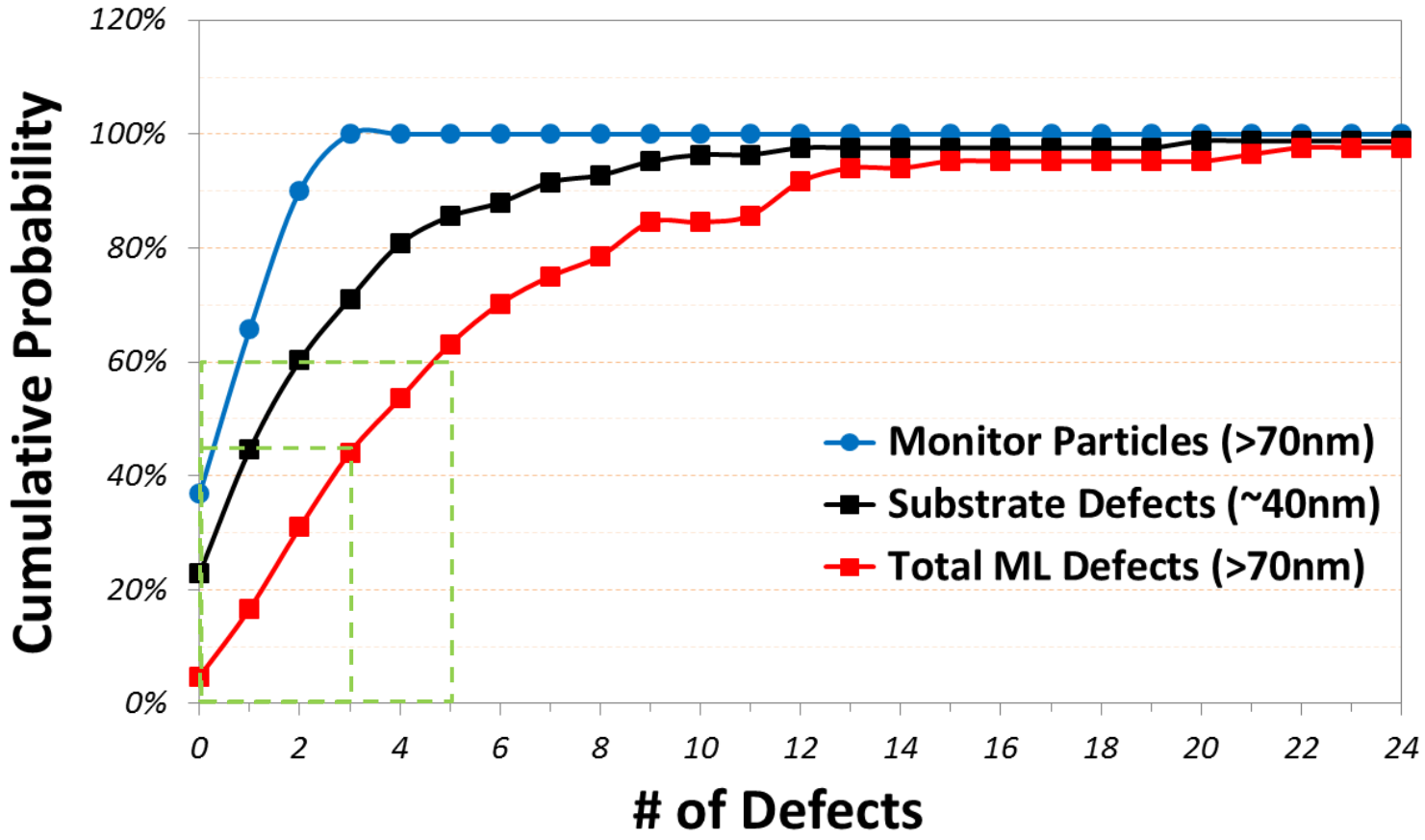




Sensitivity cut-off: ~50nm

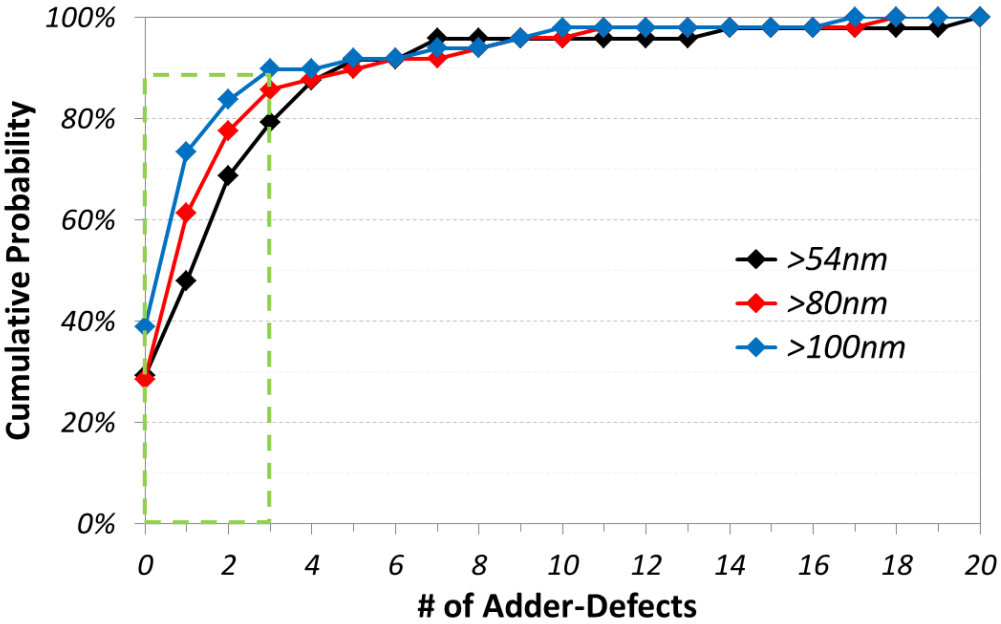
Significant Mask Blank Multilayer Yields

- **~5% yield of zero *total*-defects, >40% of 3 *total*-defects, etc.**
- **Substrate yielded at ~20%, contributed about half of ML defects**



Distribution functions, or ***yields as functions of defects*** for 50 ML blanks (NEW), substrates as used, and particle monitors run in the same period

ML Deposition Yield: *~80% of ≤3 Adder-Defects*



Mask blank yields on adder-defects for cutoff at 54nm, 80nm and 100nm, respectively

50 ML mask blanks included (NEW), all with Si-capping

ML yields of adder-defects:

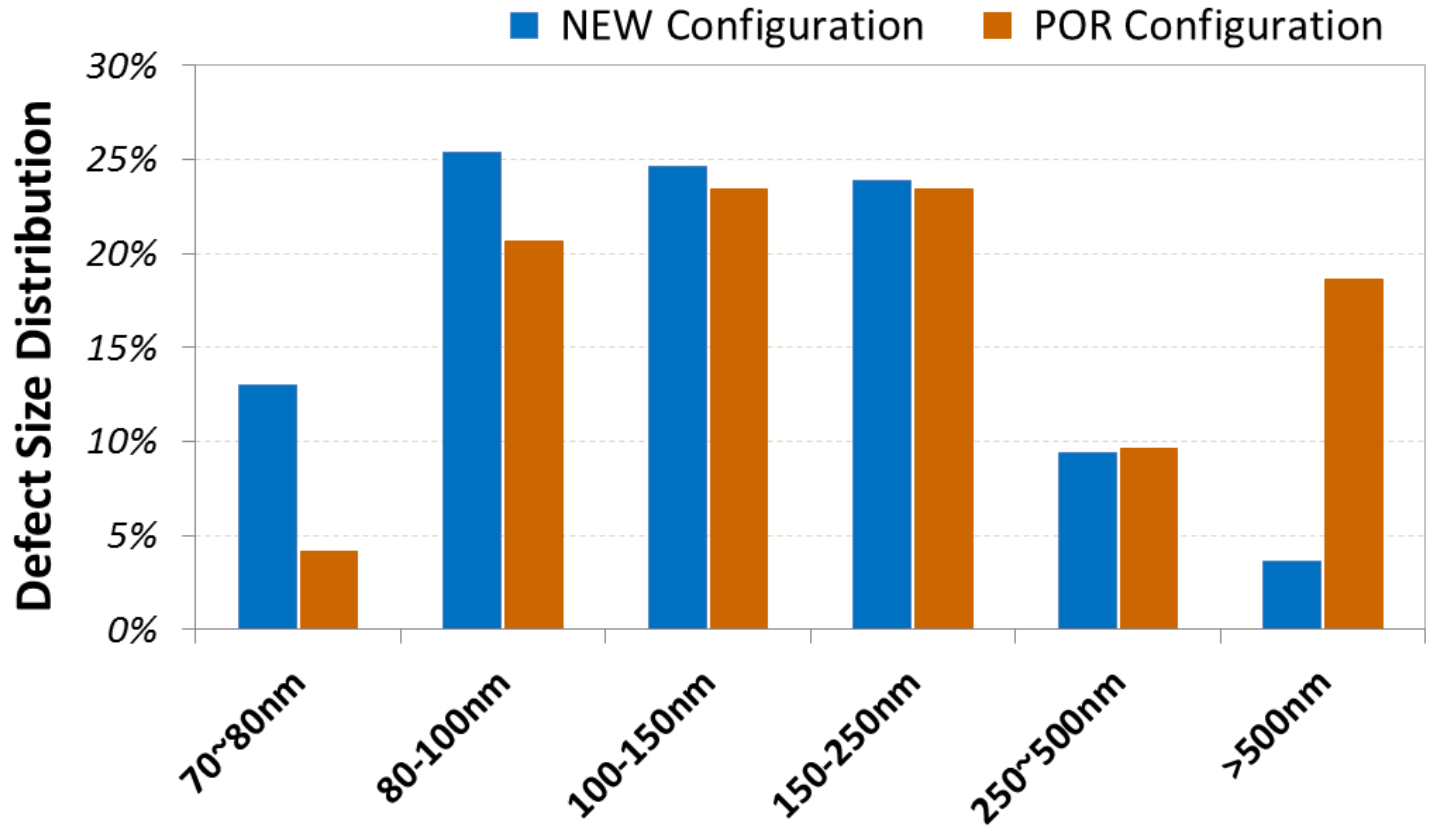
	0 defect	≤1 defect	≤3 defects
@54m/M7360	*28%*	*47%*	***78%***
@80nm/M1350	*28%*	*60%*	***84%***
@100nm/M1350	*38%*	*72%*	***88%***

ML yields of *total*-defects:

SPEC Assumed	Yield
0 defect, >54nm	***4%***
<5 defects, <80nm	***10%*** *(Actual data: 1 defect)*
<5 defects, <100nm	***20%***

Multilayer Adder Defects: *Size Distribution*

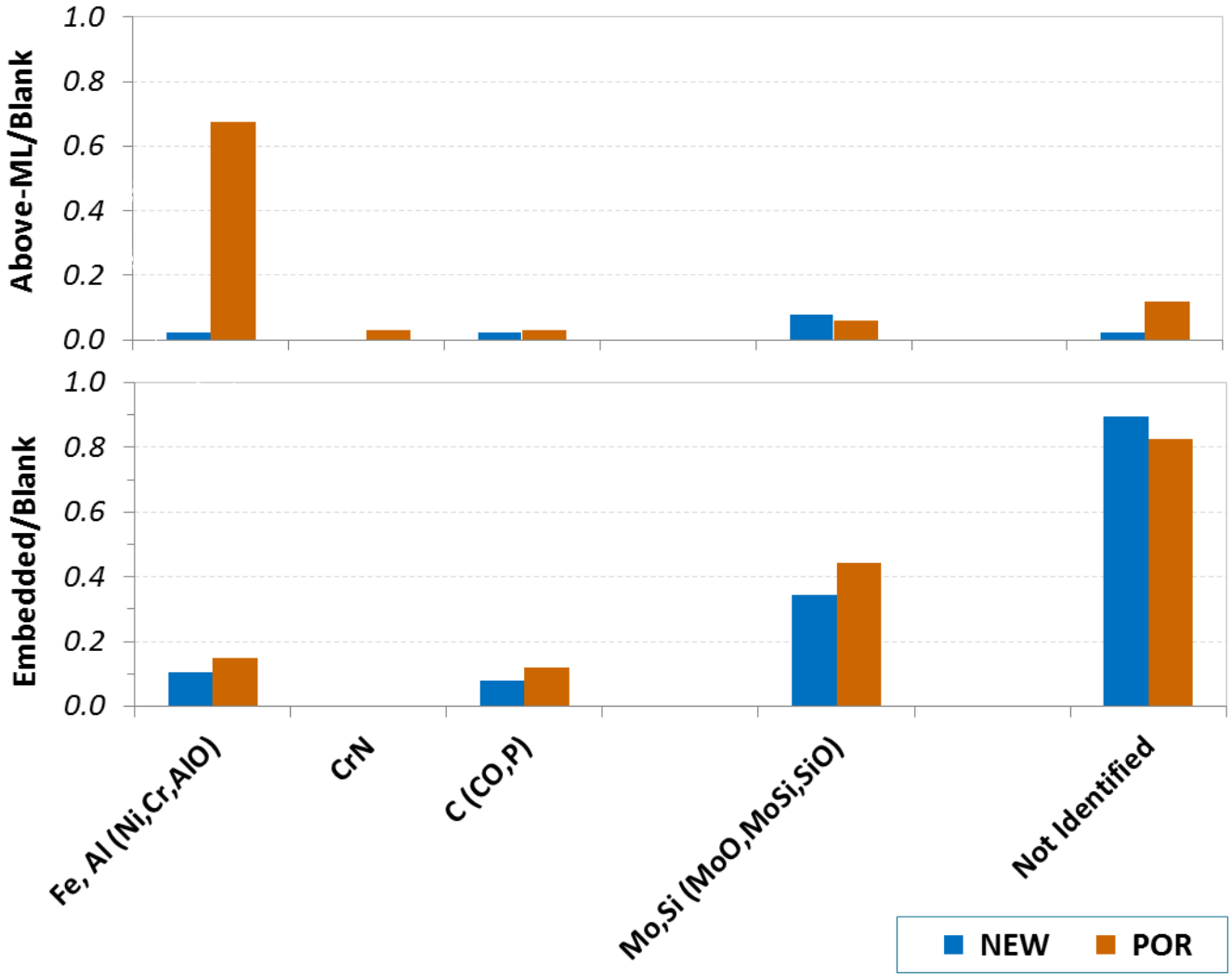
About 3 out of 4 defects range from ~80 to ~250nm.

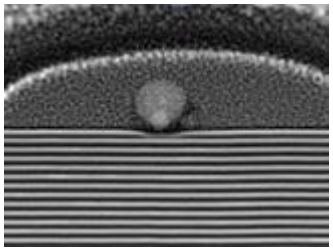


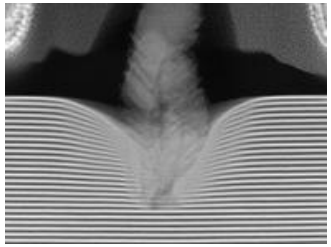
Defect size distributions of 50 ML blanks with NEW ion optics configuration and 35 ML blanks with POR configuration

ML Adder-Defect Composition: *Pareto*

All embedded and surface defects appear similar between POR & NEW, ***except surface Fe/Al defects***.



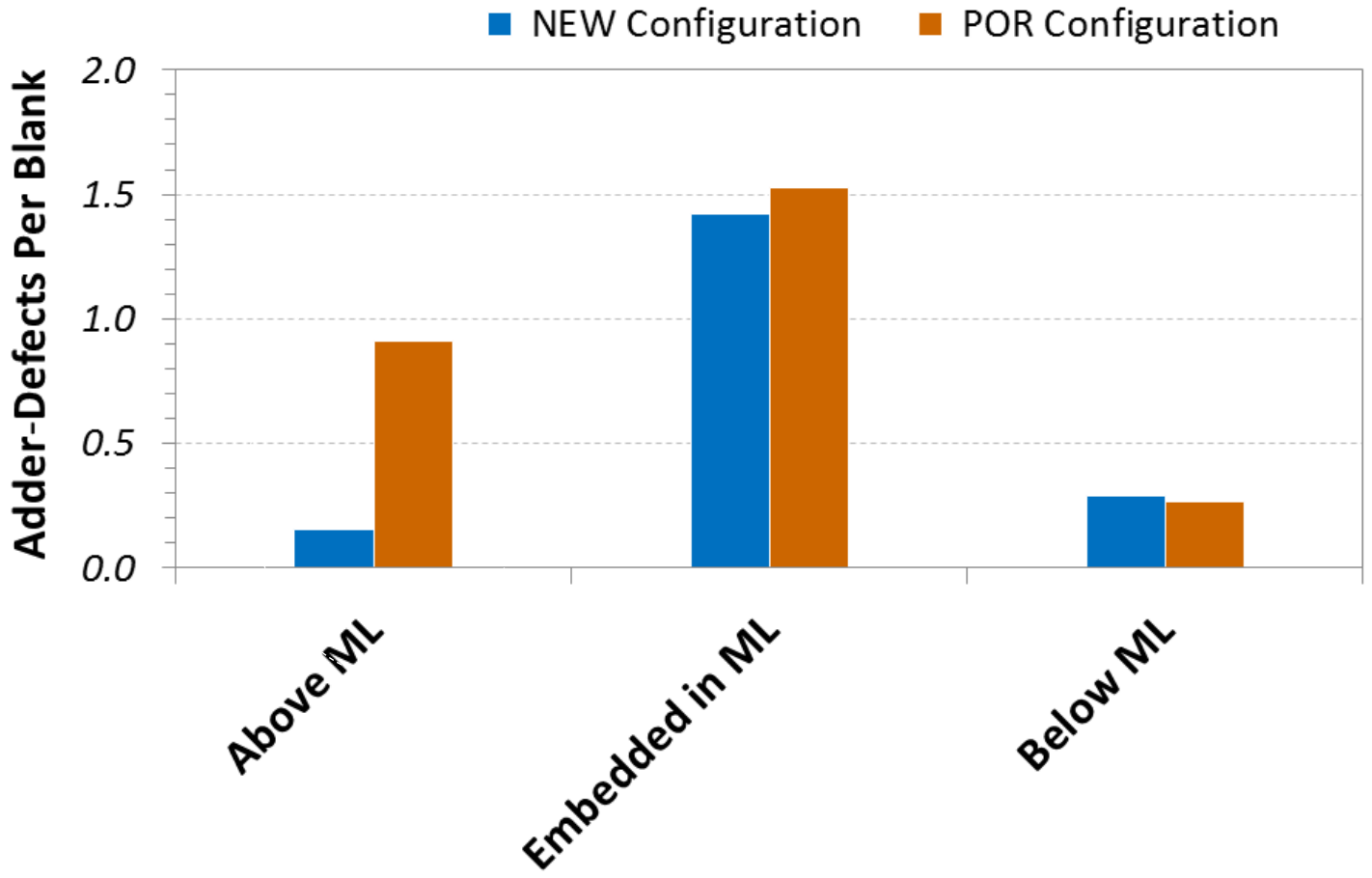




ML Adder-Defects: *Z-Location Distribution*

Confirming significantly more surface defects on POR blanks

Fe, Al compositions dominate in surface defects, *from prior slide*.
(composition-not-identified (small) defects included)

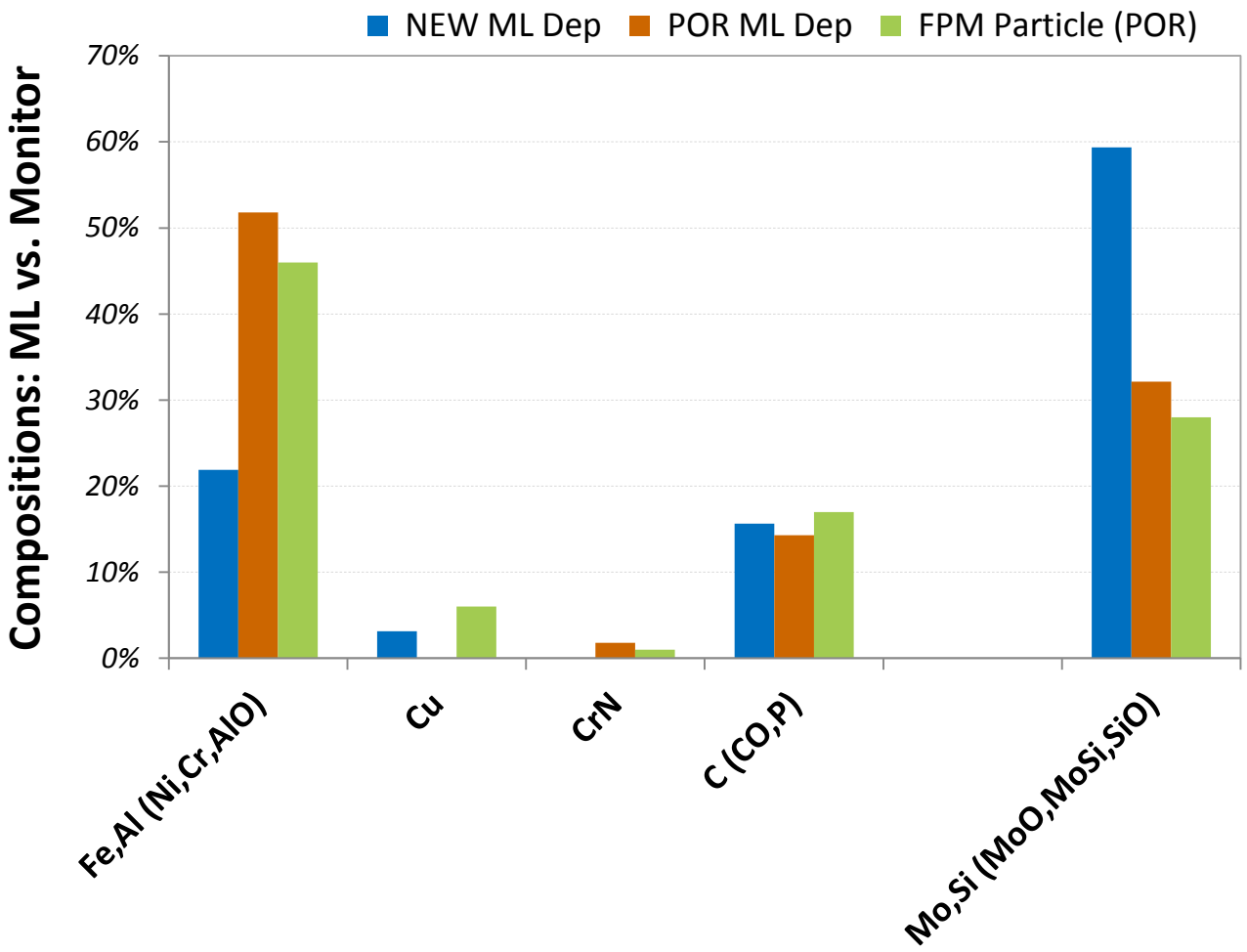


ML Defect Composition: *Follows Particle Monitor*

Compositions similar between FPM monitors & POR blanks

FPM improved before NEW blank dep, no similarity expected w/earlier FPM

(Too few particles from new FPM baseline to compare with NEW blanks)



~1 Mo,Si defect per blank estimated for both POR and NEW

Comparative Data Recap

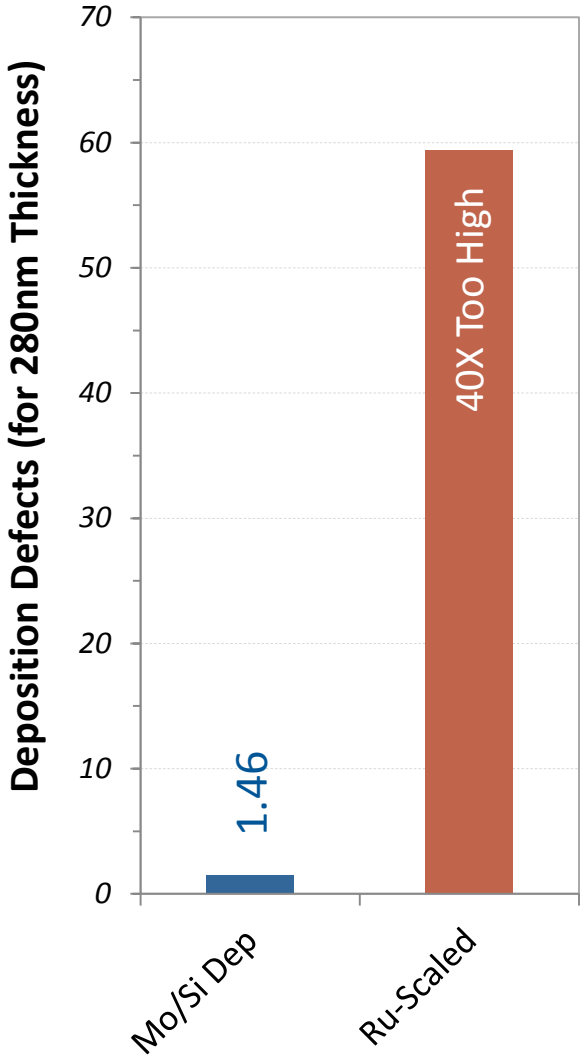
Data	NEW-Configuration	POR-Configuration	Comparison
Yields	As discussed	Not discussed	
Adder-defects per blank	Median: 1, Ave: 2.2	Median: 2, Ave: 3.6	Different
FPM particle monitors	Median: 0, Ave: 0.4	Median: 1, Ave: 1.2	Different
Embedded-defects* per blank, by elements	Mo, Si: ~0.92 All others: ~0.50	Mo, Si: ~0.95 All others: ~0.57	On par
Surface-defects* per blank, by elements	Fe/Al: ~0.03 All others: ~0.12	Fe/Al: ~0.78 All others: ~0.13	Fe/Al: different Other elements: On par
Defect z-location distributions * (defects per blank)	Surface: ~0.16 Embedded: ~1.42 Under ML: ~0.29	Surface: ~0.91 Embedded: ~1.53 Under ML: ~0.27	Surface defect: different Embedded: On par Under ML: On par
Adder-defect compositions vs. FPM	*(Too few FPM particles)*	ML follows FPM particles	
Adder-defect size distributions	80nm - 250nm *(3 out of 4 defects)* <70nm: ~10% more	80nm - 250nm *(3 out of 4 defects)* >500nm: ~15% more	On par Different

**Over 30 blanks are included in the analyses from both NEW and POR.*

Ru Defect Baseline: *Improvement Needed*

- **Mo/Si ML stack – 1.4 defects**
  (40 Mo/Si pairs)
- **Ru capping – 0.6 defects**
  (1 Ru layer)

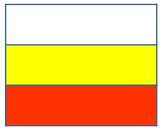
Mo/Si ML deposition defects (right)
vs.
Ru-defects if scaled to the same thickness as full Mo/Si stack



HVM Solution is Within Reach: *Further Improvements Needed*

Target Area	Benchmark	Improvement Required
Technology defect *(Compositions including Mo, Si)*	**~1.0 defect** *(per blank)*	**Mo/Si deposition, targets, shields, ion source component**
Ru defect	**~0.6 defects** *(per blank)*	**Ru defect reduction**
Mechanical particle performance *(full path monitor)*	**~0.4 particles** *(per run)*	**Tooling, manufacturability**
Substrate quality	**Low Yield**	**Production-worthy yield**
Substrate, blank inspection	**Insufficient Sensitivity**	**Advanced capability**

Long term baselines established, continuous improvements needed:
Some capabilities demonstrated, significant improvements needed:
Technology solutions do not exist today:



Conclusions

- **SEMATECH has recently demonstrated milestone EUV mask blank multilayer yields on both *total*- and *adder*-defects (Si-capping).**
  - **4% yield of *total*-defect free mask blank multilayers,** @54nm, SiO2-equivalent
  - **~40% yields on ≤3 *total*-defects,** @80nm
  - **~80% yields on ≤3 *adder*-defects,** @80nm
- **A manufacturing solution for EUV mask blanks is within reach. Significant improvements in both tooling and deposition technologies are required.**

  (Reassessment will be needed when inspection capability becomes available below 50nm.)